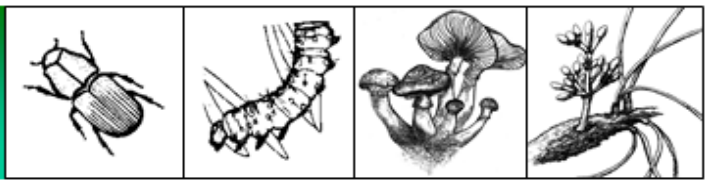
Forest Health Protection



*18-07* *MARCH 2018*

# Management and Research Goals for Balsam Woolly Adelgid in the Interior West

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## Executive Summary

The non-native, balsam woolly adelgid, *Adelges piceae* (Ratzeburg) (BWA) is killing true fir forests of the Interior West. Of the western North American fir species, subalpine fir is the most susceptible and grand fir and white fir are moderately susceptible. The future of high-elevation forests is a primary concern due to the loss of whitebark pine, limber pine, and Engelmann spruce during recent bark beetle outbreaks. The persistence of white pine blister rust has also contributed to the loss of whitebark pine and limber pine. In many locations, only subalpine fir remains to provide for critical resource values including watershed protection and wildlife habitat. The threat BWA poses to subalpine fir is expected to rise with climate change. Climatic models predict warmer winters and drier summers for much of the Interior West. Warmer winters will enable BWA survival and reproduction in historically cooler high elevation forests, while drier summers will stress host trees and likely reduce the length of time for BWA to kill those trees.

Management and research goals:

- Detection surveys throughout the native range of true fir hosts
- Long-term monitoring of true fir mortality to better understand effects caused by BWA and environmental consequences
- Temperature thresholds for BWA in the Interior West and consequences of BWA-interactions with other damage agents
- Technology development of viable management options that include biological control and genetic resistance
- Tools for technology transfer to managers and the public

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## Introduction

Invasive species pose significant threats to our Nation's ecosystems (Klepzig 2009). The non-native, invasive balsam woolly adelgid, *Adelges piceae* (Ratzeburg) (BWA) is a threat to true firs (*Abies* species) and associated habitats. There are three known subspecies of BWA in North America. *Adelges piceae piceae* infest trees in the western and the southeastern states, *A. piceae canadensis* have generally been observed in the northeastern states, and *A. piceae occidentalis* occurs in British Columbia (Foottit and Mackauer 1983, Hain 1988). By the late 1960s, BWA was common throughout the ranges of native firs in the eastern United States and along the Pacific Northwest coast. Balsam woolly adelgid was first observed east of the Columbia River Basin in the early 1970s and continues to spread eastward through native fir forests of the Interior West (MT, ID, UT). The range of BWA in Idaho and Montana has been delineated from roadside surveys, ground surveys, and aerial observations since the 1980s (Figure 1). Balsam woolly adelgid populations infesting landscapes in Idaho, Montana, and Utah have only been identified to species, not subspecies.

Range expansion of BWA may be constrained by low temperatures. Between 2008 and 2013, a trend was observed across 37 long-term monitoring locations for BWA in northeastern Oregon and throughout Idaho; a greater number of subalpine fir were infested or dying below 6,000 feet elevation than above 6,000 feet (Spiegel, personal communication, Davis et al. 2015). Ground detection surveys between 2006 and 2010 in central Idaho showed similar trends with more BWA infestations below 6,000 feet than above 6,000 feet elevation (Lowrey 2015a). However, a trend of about 30 percent host tree mortality across all size classes was documented in subalpine fir (*A. lasiocarpa*) forests above 6,000 feet in central Idaho (Lowrey 2015b). In Utah, BWA infestations have been detected at elevations approaching 9,000 feet (Malesky and Lowrey 2018). Annual aerial detection surveys between 2012 and 2017 suggested that the range of BWA-caused fir mortality continues to expand and kill its host.

## Balsam woolly adelgid

In North America, BWA populations are comprised of females and do not require males to reproduce. The insect typically produces two or more generations per year with females laying between 50 and 200 eggs (Bryant 1974, Hain 1988). Thus, only one individual is required to initiate a new population. Reproductive success and offspring survival is affected by weather and host tree vigor (Schooley and Bryant 1978). Dispersal occurs only during the first instar (crawler stage), which is passively carried by wind, animals, and humans. Human facilitated movement can occur through the transport of infested nursery stock and perhaps firewood (Woods and Atkins 1967).

Balsam woolly adelgid infests the main stem or bole, branches and branch nodes of trees. Branch node infestations can induce gouting or deform growth, reduce cone production, stimulate needle loss, and can cause mortality of saplings. Stem infestations that stimulate needle loss often lead to mortality in as little as three years, or may span decades (Mitchell 1966, Mitchell and Buffam 2001, and Overhulser et al. 2004). Bole infestations often cause the development of compression wood, where a section of the cambium dies (Doerksen and Mitchell 1965, Timell 1986).

Unseasonably cold temperatures before BWA initiates cold-hardening in the fall or after the loss of cold-hardening in the spring can cause high levels of mortality. Greenbank (1970) reported nymphs that were cold-hardened survived temperatures down to -23°F, while after they lost cold-hardiness they survived only to -14.5°F. Quiring et al. (2008) reported that host trees were not damaged by BWA in the

Maritime Provinces, where mean January temperature was 12.2°F or below. Warmer temperatures over the last decade and predicted increased temperatures for the Interior West, could lead to increased populations of BWA in historically cooler high elevation forests (Little et al. 2010).

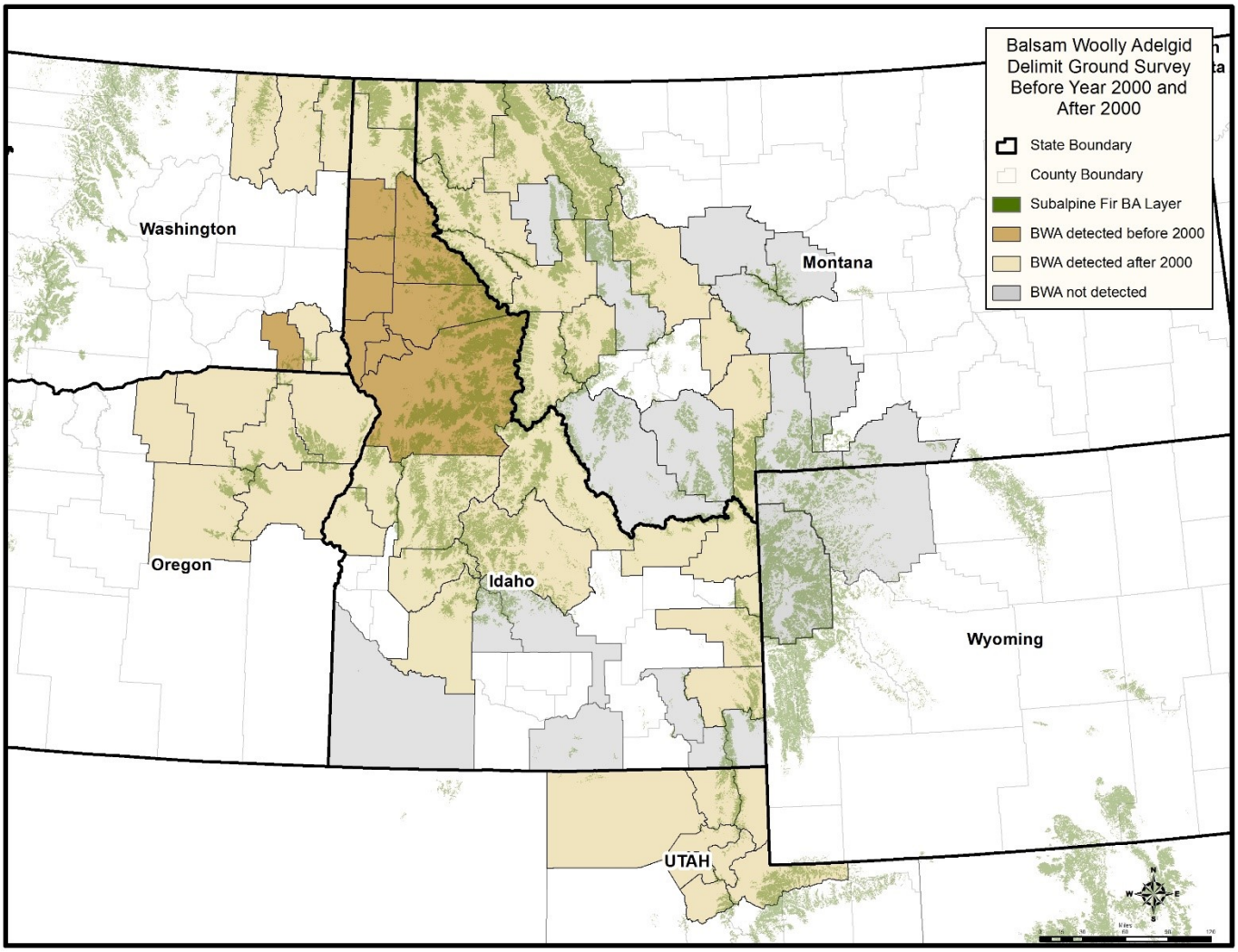


**Figure 1.** Range of balsam woolly adelgid (BWA) in the interior western United States. Populations of BWA may have been undetected because entire counties were not surveyed and only lower portions of the trees were examined.

## Host susceptibility

Susceptibility of true fir species to BWA varies widely within and among species. North American species are most susceptible and Asian and European species are least susceptible (Mitchell 1966). Of the western North American fir species, subalpine fir (*A. lasiocarpa*) is the most susceptible. Though mortality occurs for all species, resistance is likely greater for the other true firs of the interior west: grand fir (*A. grandis*), red fir (*A. magnifica*), white fir (*A. concolor*) were less susceptible to BWA in the Pacific Northwest (Hain 1988). Mitchell (1966) found that within five years of infestation, up to 90% of stands dominated by subalpine fir died, while 70% and 30% of stands dominated by Pacific fir (*A. amabilis*) and grand fir died, respectively. Host susceptibility is probably influenced by genetic variation within species and environmental effects on the host-agent interaction (Hain 1988). The greatest mortality occurs at 25-35 years for vigorously growing trees (Hain 1988). As infestations on the landscape progress, generally, older and less vigorous trees were more susceptible to BWA than younger and more vigorous trees that survived and recovered from infestations in the Pacific Northwest (Mitchell

1966, Schooley and Bryant 1978). However, Fraser fir (*Abies fraseri*), balsam fir (*Abies balsamea*), subalpine fir, and corkbark fir (*Abies lasiocarpa var. arizonica*) were particularly susceptible even when young (Mitchell and Buffam 2001).

Synergy of BWA with other biotic and/or abiotic stresses may accelerate mortality of the host. The physiological water stress caused by BWA feeding, exacerbates any existing water stress from environmental conditions. Balsam woolly adelgid infestations led to increased Armillaria root rot infections in balsam fir in Newfoundland, Canada (Hudak and Singh 1970) and may increase the likelihood of true fir dying from defoliator feeding (Mitchell and Buffman 2001). Interactions with other damaging agents in the Interior West have not been investigated.

## Value of subalpine fir

Subalpine fir will likely be the most affected species of Interior West forests as BWA continues its eastward expansion (Table 1 and 2). Subalpine firs are valuable for aesthetics and recreation, ecological function related to wildlife habitat, and regulating water flow and snow melt, and providing for wildlife habitat, Christmas tree industry, and timber. Although subalpine fir is not a primary timber species in Interior West forests, it has an estimated value in the billions based on Forest Inventory and Analysis volumes and purchase estimates (Menlove 2015, Idaho Forest Group, personal communication 2015).

Societal and ecological importance of subalpine fir increases in high elevation forests and sensitive riparian areas where timber harvest is usually restricted or not feasible. The future of high-elevation forests is of most concern where forest types are dominated by few species. The future of five needled pines is uncertain due to climate change, bark beetle outbreaks, and white pine blister rust (Keane et al. 2017). Spruce beetle has reduced the amount of mature Engelmann spruce (*Picea engelmannii*) from many high-elevation forests.

**Table 1.** Total acres of forested land, acres of subalpine fir forests, spruce-fir forests with live subalpine fir growing stock (>5" diameter at breast height (dbh)), and percent of forest with host trees across all ownerships, in six states, based on EVALIDator PC tool, which is available from the FIA DataMart (FIADB 2016, Miles 2016).

| State | Total Forested Acres | Acres with subalpine fir | Acres with spruce-fir | Percent of Forest with Host Trees |
|---|---|---|---|---|
| **ID** | 21,636,372 | 1,689,642 | 1,679,095 | 15.6 |
| **MT** | 25,912,328 | 1,540,021 | 2,753,786 | 16.6 |
| **WY** | 10,442,192 | 974,554 | 1,419,492 | 22.9 |
| **CO** | 22,858,734 | 507,785 | 2,127,267 | 11.5 |
| **UT** | 18,125,422 | 340,293 | 454,651 | 4.4 |
| **NV** | 10,518,258 | 16,977 | 0 | 0.2 |

**Table 2.** Estimated total acres of subalpine fir dominant forest with live subalpine fir growing stock (>5" diameter at breast height (dbh)) by major land ownership groups, in six states, based on EVALIDator PC tool, which is available from the FIA DataMart (FIADB 2016, Miles 2016).

| State | National Forests | National Parks | Bureau of Land Mangt. | State | Private |
|---|---|---|---|---|---|
| **ID** | 1,556,535 | 0 | 32,111 | 44,636 | 56,359 |
| **MT** | 1,301,928 | 108,496 | 5,628 | 24,592 | 99,376 |
| **WY** | 779,211 | 115,319 | 51,333 | 11,993 | 16,698 |
| **CO** | 416,661 | 0 | 30,116 | 6,518 | 54,491 |
| **UT** | 281,060 | 0 | 17,566 | 7,604 | 34,062 |
| **NV** | 16,977 | 0 | 0 | 0 | 0 |

The importance of subalpine fir for watershed protection and management has increased with the loss of other high elevation conifer species. Most annual precipitation falls as snow at these high elevations in the cold, semi-arid ranges of the middle and northern Rocky Mountains. Subalpine fir forests delay snowmelt, retain snowdrifts, regulate snowmelt and runoff more efficiently into mid-summer than non-forested areas (Jones 2000, Farnes 1990). Regulated water flow through the summer is vital for wildlife, irrigation and domestic animals in the Interior West. Moderating snowmelt may also create favorable microclimate sites for seedling establishment in these otherwise arid environments (Farnes 1990).

Subalpine fir is frequently the pioneer species on talus slopes and avalanche chutes. Subalpine firs' ability to thrive in a wide variety of soils and climates, survive frost in any month, and pioneer harsh sites makes it an invaluable ecosystem component as the climate becomes more unpredictable (Alexander et al. 1984). Subalpine fir is also known to be an important winter food and structural habitat for numerous animals such as moose, mountain goats, blue grouse, grizzly bears, woodland caribou, and pollinators (Peek 1974, Saunders 1955, Steele et al. 1981, Blanchard 1980, Mattson et al. 1986, Cooper et al. 1987, Goulson et al. 2008). Lastly, the impacts of losing subalpine fir within riparian areas are largely unknown. Evans et al. (2001) predicted many cascading impacts to aquatic ecosystem dynamics as riparian species convert from subalpine fir to hardwood shrub and tree species. Potential impacts on threatened and endangered fish species, such as cutthroat and bull trout, are unknown.

## Management Options and Recommendations for Needed Research:

Depending upon land management objectives for a particular stand, watershed, landscape, or geographic region, there are several options for managing BWA. Ascertaining the viability of some of these options will depend on filling known research gaps. Taking actions to completely remove BWA from western ecosystems is unrealistic as populations are already widespread and the insect disperses by wind. Early detection, monitoring, and refining management and restoration tactics should be undertaken to better understand BWA spread and the impact BWA is having on Interior West forests, as well as, what measures are needed to maintain subalpine fir as a viable component within high-elevation forests.

### 1) No action to manage BWA populations

No action to manage BWA would likely lead to the continued spread of BWA populations throughout the native range of true firs and widespread tree mortality. Warmer temperatures will likely increase BWA

survival rates and subsequent tree mortality, especially where minimum winter temperatures once limited BWA survival. Pacific fir has not naturally regenerated in some areas in the southern end of its historical range in Oregon following the invasion of BWA (Overhulser et al. 2004). Natural regeneration of subalpine fir, grand fir, and white fir may be at risk in some areas of the Interior West forests because all age classes of trees are susceptible to BWA infestations (Lowrey 2015b; Pederson, and Spiegel personal communications). This option may be considered unacceptable due to the ecological contributions of subalpine, grand and white fir for wildlife, watershed resiliency, and recreation.

### 2) Early detection and reducing the spread of BWA

*Detection.* Early detection of BWA is limited to ground surveys. Once BWA-infested fir trees begin to decline or die, foliar signatures can be detected during aerial detection surveys and perhaps through spectral imagery (Cook et al. 2010). However, foliar signatures can vary regionally due to environmental conditions and are not a reliable tool without extensive ground verification. New infestations can be challenging for land managers to detect, because adelgids are inconspicuous pests found in tiny bark crevices or may only be present in the upper canopy.

A native adelgid, *Pineus abietinus*, also feeds on grand fir and possibly other true firs of the Interior West at higher elevations. The impacts of this agent are generally less severe and more localized than those of BWA, e.g. no gouting symptoms (Ciesla 2011, Buxton and MacLauchlan 2013, Nathan Havill personal communication 2016). *Pineus abietinus* specimens cannot be positively distinguished from BWA in the field. Positive identification requires either microscopic inspection of morphological features or molecular diagnostics. Currently, molecular diagnostics are primarily completed by Nathan Havill, Research Entomologist, Northern Research Station.

Recommendations:

- Continue ground-based detection surveys to document the expanding distribution of BWA and confirm observations made during aerial surveys.
- Encourage all organizations conducting ground-based detections surveys to use the same methodology.
- Encourage financial support for molecular-based adelgid identification.
- Train and cooperate with state agency or university molecular labs to develop diagnostic tools for local identification.
- Obtain BWA voucher specimens in newly infested counties to officially document range expansion and subspecies.
- Refine remote sensing tools or develop new tools.
- Create identification and management guides for land managers, foresters, and the public that are specific to habitat types of subalpine and grand fir.

*Monitoring.* Long-term monitoring of BWA impacts across stand types is key to understanding the rate at which BWA induces mortality and how other biotic and environmental factors affect fir survival. Long-term monitoring plots were established throughout much of the Interior West beginning in 2008. Past monitoring programs have been challenged by limited staffing or ability to travel.

Recommendations:

- Commit FHP staff and partners to evaluate established BWA monitoring plots every five years for at least 20 years to better assess site impacts, population levels, and trends.
- Establish additional monitoring plots in Montana, Utah and Wyoming.
- Measure the intensity of BWA infestations identified by aerial detection surveys to better assess population levels and trends and site impacts.
- Evaluate potential changes to fuel loading and fire behavior of fir dominated landscapes killed by BWA.

- Encourage all organizations conducting evaluation monitoring to use the same methodology to ensure the derivation of meaningful information for all partners.

### 3) Long-term mitigation

Insecticides are effective at controlling BWA, however, they are generally limited to treating high value trees in urban forests and recreation sites. The feasibility of using insecticide treatments is presently not considered a viable option at landscape scales and necessitates further research into direct suppression tools. Silvicultural options have not yet proven to be effective for suppressing BWA, because it disperses passively, and infests trees of all sizes and vigor. Strategies for the silvicultural management of BWA, however, can focus on the maintenance of resistant trees, enhancing non-host stand components, and planting strategies. Developing effective options to manage BWA on the landscape scale are dependent on a better understanding of genetic resistance within host species, and re-examining biological control for use where populations are slowed by winter temperatures.

*Evaluate Genetic Resistance Potential.* There are limited options for reforestation at high elevations. Selecting for natural host resistance could increase survival rates of subalpine fir. Evidence of natural resistance to BWA in the West is inferred, because some firs have survived decades of infestation in Washington and Oregon. There is known variability in resistance among true fir species and within subpopulations of a species (Hain 1988, Newton and Hain 2005).

Recommendations:

- Identify individuals or populations of hosts that appear resistant or least susceptible to BWA and evaluate mechanisms of resistance.
- Initiate a gene conservation program for subalpine fir.

*Biological Control.* Biological control remains a viable option for reducing damages of BWA in the forest. Between 1957 and 1964, 23 species of BWA predators were released in Oregon and Washington from 15 countries. Four introduced species from Europe were reported as established and two additional species were recovered in the 1990s in British Columbia (Mitchell and Wright 1967). None of the introduced predators were found in areas recently surveyed in northern Idaho (Steve Cook, personal communication 2015) nor reported to provide effective management of BWA. One hypothesis of why none of the introduced predators provided effective management of BWA is that the ancestral origin of BWA is the Caucasus Mountains in Eurasia, not Europe, which was the primary source of most introduced biological control agents (Montgomery and Havill 2014).

Recommendations:

- Survey the native and introduced predator complex associated with BWA and other adelgid species.
- Continue to investigate and prove the origin(s) of BWA introduced to North America.
- Search for potential predators in country of origin and complete investigation for potential rearing and releases.

*Silvicultural Treatments*. Refining and implementing silvicultural treatments may provide an avenue for delaying the local intensification of BWA infestations and facilitate the restoration of severely impacted stands to meet resource needs in the near future, particularly, until the development of genetically resistant stock, and biological control and insecticides become viable options.

Recommendation:

- Design and implement studies, at various scales, to test the effectiveness of silvicultural treatments for reducing local population spread and enhancing non-host and resistant fir components.

### 4) Education and management decision tools

*Education:* Human assisted dispersal of BWA can be reduced through educating land managers and publics about the current distribution and tactics to mitigate its spread. Natural resource land managers, foresters, and the public that attend Forest Health Protection sponsored trainings currently receive verbal information about BWA identification, population dynamics and spread, updates regarding its distribution, impacts, new management tools, and policies. Printed and on-line reference guides will improve the ability to identify and collect specimens for molecular species confirmation, biological control and potential genetic resistance.

Recommendations:

- Increase training opportunities for land managers, foresters and the public about BWA.
- Create printed and on-line BWA awareness, identification, and management guides.
- Develop an interagency communication strategy for BWA.

*Improved Maps and Models.* Coarse scale distribution maps are useful for educating and developing region-wide strategies. Fine scale maps are needed for land managers to make stand level decisions. Probability models of tree decline due to BWA alone or when other damage-causing agents are present will allow for more informed judicious land management decisions.

Recommendations:

- Evaluate the phylogeny of BWA in relation with hosts and environmental conditions.
- Define threshold temperatures for BWA survival and incorporate into risk maps and population models.
- Develop predictive mortality models for interactions of BWA with other damage agents (i.e., fire, pathogens, and insects) and environmental conditions, such as drought.
- Develop stand hazard ratings across habitat types.

## The following entomologists provided review and support of the concepts and recommendations presented:

Steve Cook; Research Entomologist, University of Idaho, Moscow, ID
Darci Dickinson; Entomologist, US Forest Service, Region 6 Forest Health Protection, Wenatchee, WA
Amy Gannon; Program Manager, Montana Division of Natural Resources and Conservation, Missoula, MT
Fred Hain; Chair, Alliance for Saving Threatened Forests, North Carolina State University, Raleigh, NC
Nathan Havill, Research Entomologist, Northern Research Station, Hamden, CT
Lee Humble; Research Scientist, Pacific Forestry Centre, Victoria, British Columbia
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Danielle Malesky; Entomologist, US Forest Service, Region 4 Forest Health Protection, Ogden, UT
Liz Hebertson, Entomologist, US Forest Service, Region 4 Forest Health Protection, Ogden, UT
Carl Jorgensen; Entomologist, US Forest Service, Region 4 Forest Health Protection, Boise, ID

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**File Code:** 3410 **Date:** March 15, 2018
**Route To:** 3400

**Subject:** Management and Research Goals for Balsam Woolly Adelgid in the Interior West, Numbered Report, 18-7

**To:** Regional Foresters, Regions 1,2,4,6

The attached report summarizes why the non-native and invasive balsam woolly adelgid, *Adelges piceae* (Ratzeburg) (BWA), is a pest of concern, with specific focus on the Interior West. Eleven entomologists, representing federal and state agencies and universities, contributed to the described options toward long-term mitigation of future loss of true fir species due to this pest. The outlined research and management goals promote functioning high-elevation forests and complement whitebark pine restoration efforts.

Report highlights:

- All size classes of all true fir species can be killed by BWA in the Interior West.
- Subalpine fir is the most susceptible fir species, dying in as little as one year of infestation.
- Climate change is predicted to continue to exacerbate mortality of true fir on the landscape, especially in dry forests of low diversity.
- Multiple approaches are recommended to fill current management needs, as BWA continues to spread eastward and southward.

We hope this information provides a foundation for further discussion on how some, or all, of the outlined options may be implemented. Please contact Laura Lowrey, FHP Boise Field Office, 208-373-4226, or Gina Davis, FHP Coeur D'Alene Field Office, 208-765-7342, for additional assistance.

*/s/Gina Davis (for):*
MIKE DUDLEY
Director State and Private Forestry, Northern and Intermountain Regions

Enclosure:

cc: Mike Dudley, John T. Shannon, Gina Davis, Laura Lowry, Debbie Hollen, Roy Mask, Lia Spiegel, Darci Dickenson, Joel McMillin, Amy Gannon, Steve Cook, Fred Hain, Nathan Havill, Lee Pederson, Danielle Malesky, Liz Hebertson, Lee Humble, Rob Cruz, Marcus Jackson, Rob Rabaglia